Biofiltration Strips
Design Guidance

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Division of Environmental Analysis
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For any discrepancies between the information provided in this guidance document and the Project Planning and Design Guide (*PPDG*), the *PPDG* will govern.

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BMP	Best Management Practice
ft	feet
DPP BMP	Design Pollution Prevention BMP
HDM	Highway Design Manual
HRT	Hydraulic Residence Time
in	inches
max	maximum
min	minimum
NPDES	National Pollutant Discharge Elimination System
PS&E	Plans, Specifications and Estimate
RWQCB	Regional Water Quality Control Board
sec	second
TSS	total suspended solids
WQF	Water Quality Flow

1. Introduction

1.1. *Overview*

This document provides guidance for Caltrans Project Engineers and District Landscape Architects for incorporating Biofiltration Strip Treatment Best Management Practices (BMPs) into projects during the planning and design phases of Caltrans highways and facilities. The primary functions of this document are to:

1) Assist with determining the applicability of a Biofiltration Strip (“BioStrip”);

2) Provide the design guidance;

3) Cover the required elements for implementing a Biofiltration Strip in a PS&E package (Plans, Specifications, and Estimates) for a given project;

4) In an Appendix (separate attachment), information is presented about vegetation in BioStrips.

The Project Engineer and the District Landscape Architect have different perspectives and responsibilities during the design of BioStrips. Guidance is provided to the Project Engineer in this document, while guidance to the Landscape Architect is provided in the Appendix (separate attachment); the latter guidance is considered the best available at this time, but the Headquarters Office of Roadside Management will develop and issue additional guidance as needed.

1.2. *Biofiltration Strips – A Brief Description*

Biofiltration Strips are one of several BMPs for treatment of stormwater runoff from project areas that are anticipated to produce pollutants of concern (e.g., roadways, parking lots, maintenance facilities, etc.). BioStrips are sloped vegetated land areas located adjacent to impervious areas, over which storm water runoff flows as sheet flow. Pollutants are removed by filtration through the vegetation, uptake by plant biomass, sedimentation, adsorption to soil particles, and infiltration through the soil.

BioStrips are effective at trapping litter, Total Suspended Solids (soil particles), and particulate metals (Caltrans, 2002).

The following list demonstrates some advantages of utilizing a BioStrip as a Treatment Control BMP.

1. When properly implemented, Biostrips are aesthetically pleasing. Due to the presence of its vegetation, the public views Biostrips as a “landscaped roadside”

which would make placement more acceptable than other Treatment BMPs using concrete vaults.

2. Biostrips were determined to be an effective Treatment BMP in reducing sediment and heavy metals, as described in the *BMP Retrofit Pilot Program Final Report* (Caltrans, 2004)
3. In that same report Biostrips were determined to be cost effective and, together with Bioswales, were among the least expensive Treatment BMP per volume of runoff treated.
4. Biostrips also are well suited to being part of a “treatment-train” system of BMPs and should be considered whenever siting other BMPs that could benefit from pretreatment, especially Bioswales, Infiltration Basins, Infiltration Trenches, and Wet Basins. When there are right of way restrictions there may be occasions to use a lined ditch at the downstream edge of a Biostrip. A lined ditch will reduce the width and possibly the slope of the ditch, if needed, and are typically less wide than a vegetated swale of equal hydraulic capacity. For instance if there is only 18 feet of roadside between the edge of pavement and the right of way fence , it may be better to have a 15 foot Biostrip and a 3 foot lined ditch instead of a 10 foot Biostrip and a 5 foot Bioswale.

A schematic of a BioStrip adjacent to a Biofiltration Swale is shown below.

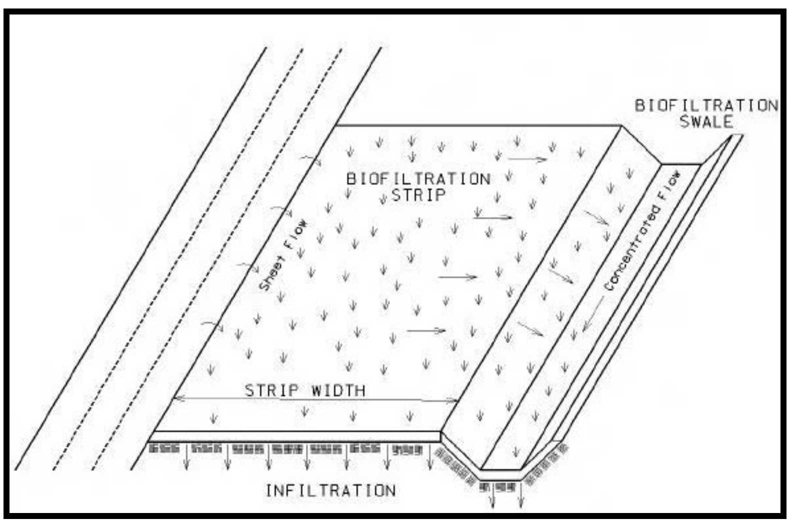

Figure 1-1 Schematic of Biofiltration Swale and Strip

Figure 1-2 Biofiltration Strip (District 7, I-605/SR-91)

2. Basis Of Biofiltration Strip Design

2.1. DESIGN CRITERIA

To perform as an effective Treatment BMP, the Biofiltration Strip must meet certain design criteria, taken from the *Project Planning and Design Guide* (*PPDG*):

Table 2-1 Biofiltration Strip Design Criteria

Parameter	Min. Value	Max. Value
Flow Rate, cfs	For water quality treatment: WQF	None, except that the site must not be considered erodible during larger rainfall intensities
Side Slope Ratio	Must grade to drain, but no minimum limit; 4H:1V preferred (refer to *HDM* 304.1 for further discussion of slopes).	Slope must support required vegetation; see also see also Section 2.3
Tributary Area	No minimum length (length of flow path)	150 ft maximum, but consult District NPDES Coordinator if longer
Biofiltration Strip Length (Direction of Flow), ft	15 ft unless supported by RVTS; see also Section 2.3	100 ft
Biofiltration Strip Width (perpendicular to flow, usually parallel with traffic)	No minimum value established, but should be considered in the context of the overall location; use of very short widths is discouraged, but any width can be considered; agreement with District Maintenance is required	
Manning's *n* value See Note 1	During WQF: 0.20 (routinely mowed) to 0.30 but 0.24 (infrequently mowed) recommended. See Note 1	
WQF Velocity, V_{WQF}	No minimum value	1.0 fps, but seldom controls design
Flow Depth (WQF), d_{WQF}	No minimum value	1.0 inch, but seldom controls design
Vegetative Coverage and Type;	70 % minimum coverage (see Note 2); Vegetative Type - See Appendix A (separate attachment)	
Hydraulic Residence Time	No minimum required; the Biofiltration Strip Length controls	
Hydraulic conductivity (permeability) of the soils	No value set, but it is acknowledged that a percentage of the treatment is made via infiltration. Consider conductivity only in the context of vegetation purposes.	

1) Refer to HDM Table 816.6A. If the proposed grass type or its conditions are not known, use n = 0.24. If the grass is known refer to FHWA HEC 15, Design of Roadside Channels with Flexible Linings, (2nd ed., April 1988, Table 1 and Charts 5, 6, 7, and 8) or the 3rd ed, Sept. 2005, chapter 4.1. The use of 0.24 is adequate for almost all situations, as Manning's Equation would be used to calculate the velocity and the depth, and these parameters seldom control the design. Soil amendments (such as compost material) may increase Manning's n value; support use of any higher value in the Storm Water Data Report.
2) Vegetative cover is the percentage of soil surface in contact with plant stems and leaves including the area covered by leaves, stems, or other plant parts that extend no more than 12-inches above the ground surface.

2.2. *Restrictions*

Successful implementation and utilization of the BioStrip as a BMP will require proper siting by coordinating with District Hydraulics, District Maintenance, and District Landscape Architecture. A BioStrip should not be designed outside the values presented in Table 2-1 without consultation with the District NPDES Design Coordinator.

Additional restrictions applicable to the use of the BioStrip BMP Detail Drawings are as follows:

- Biostrips in arid regions will require installation of a temporary (or permanent) irrigation system to ensure 70 percent vegetative coverage, and/or must be planted with vegetation that will go dormant outside of the rainy season; consult with the District Landscape Architect to verify that water is available for irrigation. Also assess feasibility. Refer to Section 2.4.2.1 of the PPDG.

- Consult with District Design NPDES Coordinator if Biostrips are proposed at locations having contaminated soils or above contaminated groundwater plumes.

- Slopes should be designed as flat as possible. For new construction, widening, or where slopes are otherwise being modified, embankment (fill) slopes should be 1:4 or flatter (Refer to HDM 304.1 for further discussion of slopes).

- BioStrips are not generally subject to setback restrictions as an Infiltration Device is; however, if unusual geotechnical conditions exist, or if a BioStrip is proposed above a retaining wall and the soils are known to be especially erodible or permeable, consult with Geotechnical Design.

- Nearby fill slopes should be observed for signs that the embankment soils are highly erodible, and the District Landscape Architect should be consulted about soil amendments, use of fiber rolls, or other methods to reduce the potential erosion.

2.3. *Minimum Biofiltration Strip Length*

Treatment is obtained by BioStrips through filtration through the vegetation, uptake by plant biomass, sedimentation, adsorption to soil particles, and infiltration through the soil. Of these mechanisms, probably the two most important are sedimentation and infiltration. The relative proportion of total treatment done by the sedimentation and infiltration can vary by site, but in terms of total pollutant load reduction (as opposed to concentration reductions) the role played by infiltration can be much more than 50% (see Reference 4, especially Figures 5 and 6). Using TSS (total suspended solids) as the key pollutant for this discussion indicated a reduction in the TSS concentration of 50% or more can occur after as little as 12 feet of travel for a variety of side slope ratios, including slopes as steep as 2H:1V. As mentioned, the concentration reduction does not fully indicate the significant reduction in loading that occurred due to the large volume of runoff infiltrated. Based on the data presented, the minimum recommended slope length for BioStrips is 15 ft for any side slope ratio as long as the site supports the required 70 percent vegetation coverage without rills or gullies; a reduced minimum length can be considered as a design exception if supported by the RVTS study with respect to: side slope ratio, percentage vegetation coverage, and soil type.

These findings about infiltration and reduction in concentration of TSS, because they are critical to understanding the recommended minimum length criteria, have been plotted on the following page to better illustrate these findings.

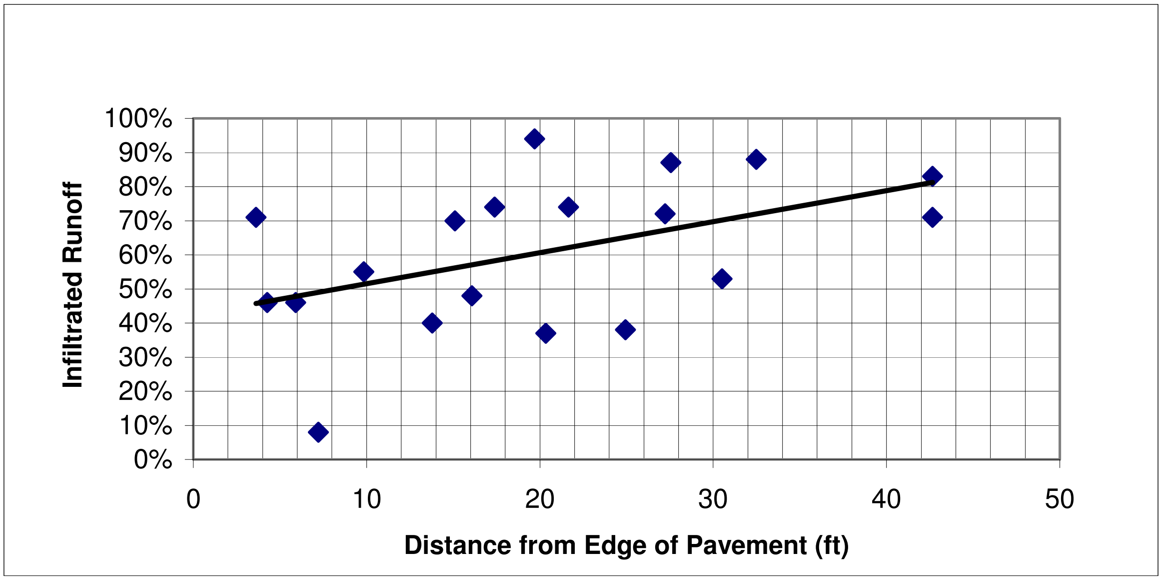

Figure 2-1 Percent of Runoff Infiltrated Vs. Distance from Edge of Pavement See Footnote 1

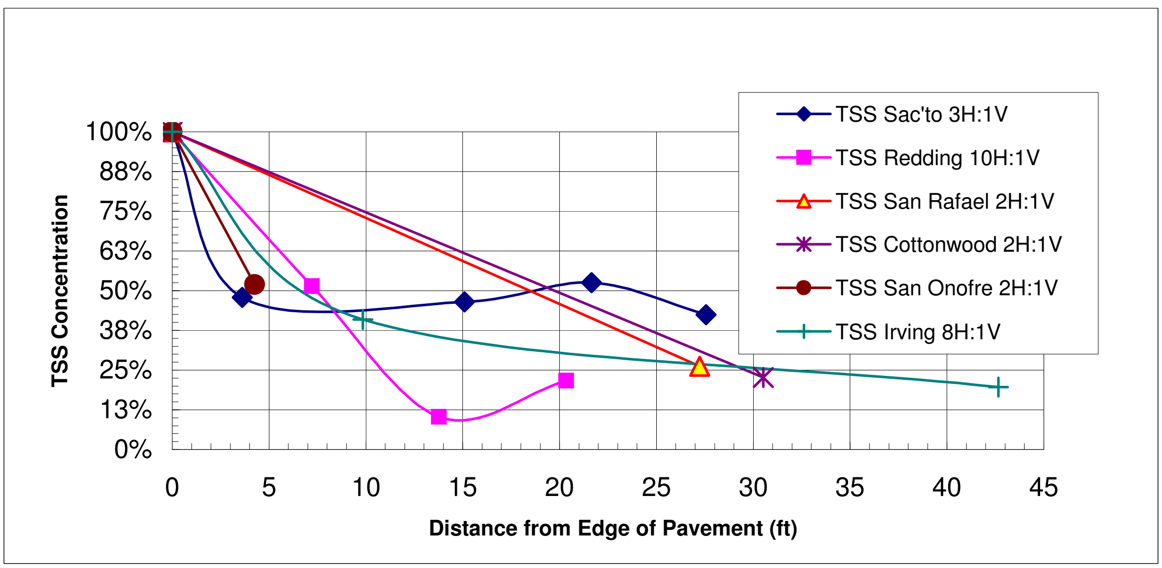

Figure 2-2 TSS Concentration Reduction Vs. Distance Edge of Pavement See Footnote 1

[1] Figures 2-1 and 2-2 based on data presented in Reference 4. Figure 2-1 presents data from seven of the eight monitored sites, ignoring only Moreno Valley (which did not meet the minimum vegetation coverage percentage). Figure 2-2 presents data from six of the eight monitored sites (ignoring Yorba Linda, where gopher activity was high, Moreno Valley, which did not meet the minimum vegetation coverage percentage, and including only the first monitoring location at San Onofre, where gopher activity was low). For both: 100% value at the edge of pavement represents runoff directly from the road surface.

3. Getting Started

Before selecting, sizing, and laying out the Biofiltration Strip, existing site conditions are evaluated to obtain and assess the necessary design parameters that will be used to determine if a BioStrip is applicable. **In general, verification of the depth of flow or velocity is not needed if the Design Criteria is used.** However, these calculations may be needed for other purposes, and are briefly discussed in this section. Since these calculations will seldom be needed for Caltrans' designs, no Design Example is provided in this document.

1. The Water Quality Flow rate (WQF)
2. Tributary Area Length (in the direction of flow)
3. Length of BioStrip in the direction of flow.
4. Surface slope of BioStrip in the direction of flow

3.1. *PRELIMINARY DESIGN PARAMETERS*

3.1.1. Rainfall Intensities and WQF

A. WQF

Design Flow: The flow used for designing BioStrips is the Water Quality Flow (WQF). The WQF may be found in the PPDG, Section 2.4.2.2, or by referring to the Basin Sizer program that has been created for Caltrans use. The Basin Sizer program, an explanation of the methodologies incorporated into the program, and a description of how to use Basin Sizer can be found at the following online link:

http://stormwater.water-programs.com/BasinSizer/Basinsizer.htm

The flow for designing BioStrips should be made using the WQF intensity, the tributary area, and the appropriate runoff coefficient, multiplied using the Rational Formula.

$$Q_{WQF} = C \times I \times A$$ See Footnote 2

where
Q_{WQF} = Water Quality Flow rate (cfs)
C = runoff coefficient
I = WQF rainfall intensity (in/hr)
A = tributary area to the BioStrip (acres)

[2] In metric units: $Q_{WQF} = 0.28\ C \times I \times A$ where Q_{WQF} is m^3/sec, C as above, intensity I as mm/hr, and area A as square kilometers.

B. Flow in the BioStrip during the Design Event: Q_{25}

The BioStrip must handle the peak drainage from the roadway. However, calculations using this intensity are not usually made, in part since there is no need for an 'overflow' device from this type of Treatment BMP.

3.2. *CALCULATIONS*

3.2.1. WQF Depth, Velocity, and Travel Time Using Manning's Equation

A. Depth

The design flow depth is calculated using a re-arranged version of Manning's equation (assumes the depth of flow is nominal with respect to the width of flow). The flow for designing BioStrips should be made using the WQF intensity, the tributary area, and the appropriate runoff coefficient, multiplied using the Rational Formula.

$$Q_{WQF} = {}^{1}/_{n} \text{ x } A \text{ x } R^{2/3} \text{ x } S^{1/2}$$

where

Q_{WQF} = flow at defined event (cfs)

n = Manning's coefficient; recommend using "n" = 0.24 for Q_{WQF}

A = Cross-sectional area of the flow in the channel, unit width (ft)

R = Hydraulic Radius = "A" / Wetted Perimeter ("P")

S = longitudinal slope (ft/ft)

Since the area A will equal the depth times the unit width, and since the wetted perimeter will also equal depth, the formula can be re-written as:

$$Q_{WQF} = ({}^{1}/_{n}) \text{ x } d^{5/3} \text{ x } S^{1/2}$$

And re-arranging to solve for depth:

$$d = [(Q_{WQF} \text{ x } n)/S^{1/2}]^{3/5}$$

where

d = Flow depth during the WQF event (ft) and all other terms as above.

The flow depth should not exceed 1 inch (Design Criteria); if it does, a reduced WQF intensity could be negotiated with the RWQCB (see *PPDG* Section 2.4.2.2), an increased slope could be made (although this will increase the velocity, so it is not the ideal adjustment), or the area could be considered as a Vegetated Surface Design Pollution

Prevention (DPP) BMP. Note: Flow depth will not control the design if the Design Criteria are otherwise followed.

B. Design Velocity

Using the depth and Q_{WQF} calculated in the steps above, velocity equals:

$$V_{WQF} = Q_{WQF} / d$$

where
V_{WQF} = Velocity during the WQF event (fps)
d = Design Flow Depth (ft)

If the design flow velocity exceeds 1.0 ft/s, a BioStrip cannot be used, unless the slope can be made flatter. Note: velocity during WQF events will not control the design if the Design Criteria are otherwise followed.

C. Hydraulic Residence Time

While there is no minimum travel time (termed the Hydraulic Residence Time [HRT]) required within the BioStrip, it may need to be calculated for other reasons. This calculation would be made after the proposed BioStrip was analyzed using Manning's Equation, as discussion above. The velocity associated with the Q_{WQF} is determined, and the HRT calculated using the proposed length of the BioStrip:

$$HRT = L / (60 \times V_{WQF})$$

where
L = proposed length of the BioStrip (ft)
HRT = Hydraulic Residence Time (minutes)
V_{WQF} = velocity at Q_{WQF} (ft/sec)
60 = conversion from seconds to minutes

3.2.2. Travel Time Using the Kinematic Wave Equation

An alternative formula is sometimes used to calculate the travel time, using the Kinematic Wave Equation presented in *HDM* Topic 816.6, Time of Concentration (T_c) and Travel Time (T_t), copied below:

$T_t = [0.93 \text{ x } L^{3/5} \text{ x } n^{3/5} / (i^{2/5} \text{ x } S^{3/10})]$ See Footnote 3

where

T_t	= travel time [HRT] (minutes)
L	= proposed length of the BioStrip (ft)
n	= Manning's coefficient; recommend using "n" = 0.24 for Q_{WQF}
i	= WQF rainfall intensity (in/hr)
S	= longitudinal slope (ft/ft)

One advantage of this formula is that it allows the HRT to be calculated directly, without first calculating the unit width Q_{WQF}. Note that this formula will calculate a longer travel time than will Manning's Equation for the shorter lengths that are typical for BioStrips, as there are different assumptions made for each of these empirical equations. If the calculation for the Hydraulic Residence Time is done at the request or to meet the requirements of an outside agency, it is recommended that this equation be used, unless otherwise directed by that agency.

[3] Using metric units: $T_t = [6.92 \text{ x } L^{3/5} \text{ x } n^{3/5} / (i^{2/5} \text{ x } S^{3/10})]$, with all terms the same, except that L is in meters, and intensity i is in mm/hr.

4. BMP Layout and Design

4.1. *Layout*

4.1.1. Location

BioStrips are probably the least expensive Treatment BMPs for an area that has already been determined to be suitable resistant to erosion without hardening. BioStrips can be a stand-alone device, or the first BMP encountered in a "treatment train". They perform well upstream of other Treatment BMPs that benefit from pretreatment such as Infiltration Devices, Detention Devices, and Wet Basins.

Narrow shoulders and conflicts with sound walls and other structures suggest that there will not be abundant opportunities for retrofit with BioStrips on existing freeways in the most highly urbanized areas.

One location that should receive special consideration is runoff at each end of a bridge structure discussed in more detail in Section 4.2.2.

4.1.2. Maintenance

BioStrips need sufficient space for maintenance and inspections along the roadways. There should be enough space for maintenance vehicles and all equipment necessary for cleaning, repair, or inspection. District Maintenance should concur that the proposed BioStrip location have adequate space and access for maintenance and inspection of the device. Refer to Caltrans Standard Plan H9, "Maintenance Vehicle Pullout" for a typical detail.

4.2. *Site Specific Design Elements*

4.2.1. Use of Level Spreaders

The *BMP Retrofit Report* discussed the use of flow spreading, and due to various difficulties, that report recommended against the use of concrete level spreaders to distribute runoff..

4.2.2. Concentrated runoff at the end of a bridge

Runoff at the end of a bridge will usually be in the form of concentrated flow, rather than sheet flow. Since the use of level spreaders is discouraged, this runoff should be considered for capture in a drainage inlet, from which it ideally would be brought to the base of the embankment and directed into a Biofiltration Swale. The remaining portion of the bridge approach would then be allowed to convey runoff as sheet flow onto BioStrips. In any event, runoff from the end of a bridge should not be allowed to cause erosion.

4.2.3. Use of Curbs and Dikes within the roadway cross section

Curbs are used when needed to improve channelization, delineation, or improving traffic flow and safety, and their use will likely not be waived due to water quality issues. However, dikes are used when deemed needed for drainage control, and can be considered in the context both of water quality and highway drainage. Use of dikes should be discouraged as much as possible on embankment sections that would otherwise meet BioStrip criteria, with agreement by District Hydraulics and Maintenance required. A further discussion about the use of curbs and dikes will be found under *HDM* Topic 303 - Curbs, Dikes, and Side Gutters.

5. PS&E Preparation

This section provides guidance for incorporating BioStrips into the PS&E package, discusses the typical specifications, and presents information about estimating the construction costs.

5.1. *PS&E Drawings*

BioStrip Treatment BMPs do not have standard drawings for the device as a complete feature, but there are several sheets that should be placed in the PS&E package. The PS&E drawings for most projects having BioStrips will include:

- **Layout(s):** Show location(s) of BioStrips. This will aid in the recognition within and outside the Department that BioStrips were placed within the project limits.

- **Contour Grading(s):** As BioStrips are primarily earthwork features they may be shown on Contour Grading sheets. Any other associated grading surrounding the BioStrip should be shown on these sheet(s).

- **Construction Details:** There will not typically be any construction details associated with BioStrips, but if there are, these sheets may be used to show these items.

- **Landscape Plans:** These sheets, and the Contour Grading sheets, will be the primary sheets used to show the placement of the landscape contract items of work for BioStrips.

- **Other Sheets:** Drainage Plans, Water Pollution Control, Erosion Control Plans, Construction Staging, Utility Plans, Irrigation Plans, and other sheets should be considered as appropriate for the construction of BioStrips on a project-specific basis.

If BioStrips will be constructed at multiple locations, a "Locations of Construction" table should be considered. This table could present the stationing and other location information. WQF could also be considered. This table may be incorporated into an existing drawing if there is room (such as a Title, Layout or Construction Detail), or may be developed as a separate drawing if necessary.

While every effort has been made to provide accurate information here, the Project Engineer is responsible for incorporating all design aspects of BioStrips into the PS&E in accordance with the requirements of Section 5 of the Department's *Plans, Specifications And Estimates Guide*.

5.2. *SPECIFICATIONS*

Contract specifications for BioStrip Treatment BMP projects will include Standard Specifications, Standard Special Provisions (SSPs), and non-Standard Special Provisions (nSSPs).[4] Where indicated below specific nSSPs have been developed by the HQ Office of Storm Water Management.

The special provisions for the various items of work directly needed to construct the BioStrip could be organized under the blanket heading of 'BioStrip' with some or all of these items listed as subheadings, and payment would be made for by 'each' BioStrip, or separate listings could be made for each contract item of work, with separate measurement and payment. The Project Engineer and the District Office Engineer should consider which method would better serve the particular project.

5.2.1. Standard Special Provisions

Listed below are SSPs that would typically be used for a project that constructs a BioStrip Treatment BMP; the Project Engineer should consider the construction of BioStrips in the context of the entire project to determine if other SSPs may be required.

- Order of Work[5] (SSP 05-010)
- Water Pollution Control (SSP 07-340 or 07-345)
- Clearing and Grubbing (SSPs 16-050, or 16-060, or 16-070)
- Earthwork (SSP 19-010; and/or Miscellaneous Earthwork Clauses, SSP 19-040; and/or Measurement And Payment (Earthwork), SSP 19-590)
- Erosion Control (Erosion Control (Type C), SSP 20-030; or Erosion Control (Type D), SSP 20-040)
- Temporary Irrigation (as Plant Establishment Work, SSP 20-550)
- Highway Planting (SSP 20-350)
- Slope Protection (SSP 72-010)

5.2.2. Non-Standard Special Provisions

Typical placement of BioStrips will not require any nSSPs. However, the Project Engineer and the District Landscape Architect must ensure that non-Standard Special Provisions, if needed, have been developed based on site-specific requirements. HQ Landscape will most likely be the approval group for any Biostrip nSSPs developed.

[4] Standard Specifications will not be included but merely referenced in the contract's special provisions.
[5] The Order of Work should indicate that no runoff from construction should be allowed to flow into the BioStrip until all upstream areas contributing runoff are stabilized.

5.3. *Project Cost Estimates*

Project Cost Estimates (PCEs) are required at every phase of the project, as discussed below. Section 7 of the *Ready-to-List and Construction Contract Award Guide (RTL Guide)* should be consulted for more details on preparing construction cost estimates.

5.3.1. *PID and PA/ED Phases*

At the PID phase of the project, the construction cost could be estimated based on the findings of the *BMP Retrofit Pilot Program Final Report*, which was at $\$21/ft^3$ of WQV treated, exclusive of right of way.[6]

To determine an initial cost estimate using this value simply use the following equation:

$$\text{Initial construction cost} = (\$21/ft^3 \times \text{run-up factor}) \times \text{tributary area} \times 0.75/12$$

This estimate will need to be modified as the project progresses. If some design is conducted during the PA/ED phase of the project, it is possible that a more refined estimate could be made using the methods in Section 5.3.2. A cost escalation should be added for projects that are anticipated to advertise more than a year after the date of the estimate.

5.3.2. *PS&E Phase*

As the design process proceeds into the PS&E phase, unit quantities would be available, and the associated unit costs need to be obtained, as accurate costs are critical. When developing costs based on unit quantities, the cost estimates should be based upon the Department's *Contract Cost Data Book* or recent, similar projects in the District, as appropriate. The Project Engineer should use SSPs and nSSPs from Sections 5.2.1 and 5.2.2 of this document, as well as those added on a project-specific basis, to develop a list of items for which item costs should be developed. The Project Engineer should carefully check that all items of work are accounted for either as pay or non-pay items.

[6] In 1999 dollars; contact District Office Engineer for appropriate run-up factors based on local experience. Note that costs were given in units more appropriate for a volume-based Treatment BMP, for comparison purposes within that report. The formula shown has been modified slightly to account for the otherwise incorrect units, and should only be used for estimating purposes in these phases of the project.

6. References

1. California Department of Transportation (Caltrans), May 2007. *Storm Water Quality Handbooks: Project Planning and Design Guide*, *(PPDG)*

2. California Department of Transportation (Caltrans), 2004. *BMP Retrofit Pilot Program Final Report,* CTSW - RT - 01 – 050

3. California Department of Transportation (Caltrans), 2004. *Roadside Vegetated Treatment Study (RVTS)*, CTSW - RT - 03 – 028

4. California Department of Transportation (Caltrans), 2006. *Final Summary Report 2006 Report Roadside Vegetated Treatment Sites (RVTS) Study*, CTSW-RT-06-127-01-2

5. California Department of Transportation (Caltrans), 2006. *Highway Design Manual*

6. FHWA, 2nd ed. August 2001. Hydraulic Engineering Circular (HEC) No. 22 *Urban Drainage Design Manual*

7. FHWA, 2nd ed. April 1988 or 3rd ed. Sept. 2005, Hydraulic Engineering Circular (HEC) 15, *Design of Roadside Channels with Flexible Linings*

8. USDA, May 1998. Forest Service, Natural Resources Conservation Service, *Ecological Subregions of California Section and Subsection Descriptions*, (online at: http://www.fs.fed.us/r5/projects/ecoregions/)

7. Biofiltration Guidance-Vegetation

7.1 Overview

This Appendix provides design guidance for the vegetative cover component of Biofiltration BMPs. For Biofiltration BMPs, District Landscape Architecture is responsible for selecting vegetation, and developing the appropriate plans, specifications, details, and estimates for contract documents. Incorporation of other improvements such as soil amendment and irrigation may be required to satisfy site conditions. For Biofiltration BMPs to be effective, it is necessary to establish a healthy, sustainable vegetative cover.

The District Landscape Architect or delegated representative is to verify that specific project requirements, necessary to provide vegetative cover for the Biofiltration BMPs, are documented in the Storm Water Data Report (SWDR) and prepared for PS&E.

7.2 Soil Testing & Investigation

It is important to identify soil characteristics of a site to determine its erosion potential and planting requirements.

The following should be considered when analyzing soils information for biofiltration BMPs:

1) Information on soils should be requested as part of the Geotechnical Investigation. Soils characteristics such as USDA Soil Group, USDA-NRCS particle distribution (soil texture), organic matter percentage, and infiltration rate (conductivity) should be requested.
2) If the Geotechnical Report has been completed without a discussion of near-surface soils information, or if no Geotech Report is prepared for the project, then the Landscape Architect should make arrangements to collect soil samples and submit them to a soils testing lab for processing. In addition to soils characteristics listed above under item 1, the soil test should also report the following:
    - pH
    - Salinity
    - Sodium
    - Boron
    - Nitrogen
    - Potassium
    - Phosphorus

3) If soils information cannot be obtained for the project site, then soils information from a reference site should be evaluated. To be valid, the reference site must have characteristics similar to the project site such as slope aspect (e.g., north-facing, etc.) topography (cut or fill slopes), climate, geology, and existing vegetation.

7.3 Soil and Planting Bed Preparation

Roadway construction that requires excavation or embankment work typically results in soils unable to support desirable vegetation. Grading operations, including compaction, produce soils of pulverized parent material with inverted soil horizons that lack nutrients, organic matter, rooting depth, and pore space. When these site conditions are anticipated, an assessment should be made by District Landscape Architecture to determine the level of treatment necessary to support vegetation.

Soil nutrients are critical to establishing and sustaining healthy vegetation. Without adequate levels of nutrients, particularly nitrogen, initial plant health and density will decline after a few years. In general, disturbed sites that have been successfully revegetated show a correlation between percent plant cover and soil nitrogen. On certain sites, plant communities with greater than 40 percent vegetative cover are associated with soil containing an average of 1100 lb total N/acre. Studies show a correlation between plant growth and the addition of nitrogen with best results occurring when nitrogen is distributed throughout the top 12-inches of soil.

Research has shown that compost and slow release fertilizers provide a better method to provide nutrients for desirable plant species than conventional commercial fertilizer. Because the nutrients provided by commercial fertilizer are readily available, the germination and growth of invasive weeds is encouraged over slower growing desirable species. Incorporating compost and applying slow-release fertilizer releases nutrients gradually, thereby promoting the germination and establishment of perennial grasses and woody shrubs. In addition to providing long-term nutritional benefits as a soil amendment, compost can be used as a 1” to 2” mulch layer to prevent the germination of most invasive annual weed species. When a compost mulch layer is specified, apply the seed on top of the compost layer to ensure that desirable seed species will germinate.

The following should be considered when preparing soil for biofiltration BMPs:

1) The soils in areas designated for biofiltration should be ripped and cultivated to a minimum depth of 12-inches to relieve surface compaction.
2) Compost should be incorporated at a minimum rate of 400 cuyd/acre (3-inch layer) to a minimum depth of 12-inches in all areas designated for biofiltration to restore soil organics, rooting depth, porosity and nutrients (carbon and nitrogen).

3) Compost incorporation is typically recommended for slopes less than or equal to 4:1 H:V. For slopes steeper than 4:1, coordinate your work with your geotechnical engineer and District NPDES Coordinator.
4) Compost incorporation is not suggested for areas where harvested topsoil will be placed. Designate topsoil harvest and stockpile locations on the plans. Include details for re-application and placement of topsoil.

7.4 Irrigation Strategies

California's diverse microclimates make establishing vegetation difficult and sometimes impossible without supplemental irrigation. Harsh site conditions often limit the ability of the plantings to survive and thrive to the extent necessary for successful treatment. Under these conditions, irrigation should be provided.

The following criteria should be considered when designing biofiltration BMPs:

1) If vegetative cover goals (minimum 70%) are not achievable under normal rainfall, then a temporary or permanent irrigation system is recommended. Irrigation for Biostrips should be either temporary for establishment of vegetation, if necessary, and permanent only if desired for aesthetic considerations (e.g. don't want a brown patch looking out of place amongst vibrantly green plantings).
2) If it's anticipated that the first storms of the rainy season will wash away the seedbed of the biofiltration BMPs, then the use of a temporary irrigation system to establish the vegetation prior to the rainy season is recommended.
3) If the proposed biofiltration BMP is adjacent to or within an irrigated landscape then utilization of the existing water service for irrigation is recommended. A bioswale or biostrip located within a landscaped urban interchange should be designed to complement the adjacent existing highway planting.

7.5 Planting Strategies

The following criteria should be used as a general measure of successful Biofiltration BMP installation:

1) Within the first year, a minimum of 70 percent vegetative cover is achieved.
2) Within three years, 75 to 85 percent vegetative cover is achieved.
3) The Biofiltration BMP does not exhibit rills, gullies, or visible erosion that is contributing to the export of sediment.

California's diverse microclimates require equally diverse strategies for successfully establishing vegetation. The following planting strategies have been successfully used for roadside revegetation and should be considered for biofiltration BMPs where appropriate:

1) Temporary cover with sufficient longevity should be provided until the desired percentage cover of vegetation is achieved. For challenging sites, it may take more then one growing season to establish adequate vegetative cover. This is especially

true for shrubs and woody perennials on harsh sites. Temporary cover is usually provided through the use of short-term, degradable erosion control products such as rolled erosion control products (RECPs), wood chips and compost, straw, and hydromulchs. These products vary in how long they will last. For example, straw can be expected to last through a single rainy season while a woven coconut fiber netting will usually persist for 3 years.

2) Strive for cost effective solutions. In most cases, the temporary cover product with the greatest longevity will also be the most expensive. While plant performance, slope steepness, slope inclination, slope aspect, and soil characteristics must be considered, avoid over-design. Specify different materials when warranted by diverse project conditions. For example, a cost-effective project design may include the use of blown straw and hydroseed on areas of good soil and gentle slopes whereas compost and coir netting are reserved for steep, cut slopes.
3) Specify drought tolerant grasses, with a goal to use as many appropriate native species as possible. Species that become dormant during the dry season are acceptable as long as this doesn't affect biofiltration performance. In Southern California, it is preferable to select plant species that are not dormant during the winter and spring (wet season).
4) Combine hydroseeding and direct planting. Some plant species favor particular planting methods, so allowances have to be made if these species are to be used. Many plant species can be applied by hydroseeding. Other plants are better established as liner, container, or plug plant material and can be installed in previously seeded areas, following germination. This method can be effective for bioswales when the upland zone on the banks is hydroseeded and the hydrophilic zone in the bed is planted with sedge, grass, and rush liners.
5) Specify pre-germination or include mulch for weed control. Pre-germination is a very effective method for killing weeds that germinate from an existing seed bank. Planting by hydroseeding or other methods should be done after one or more pre-germination cycles. Pre-germination is only practical when temporary irrigation is employed. A 1"-2" layer of compost mulch is also an effective method to prevent germination and competition from annual weeds.
6) Specify erosion control blankets or other RECPs in areas that will receive concentrated flow. Although hydroseeding may be appropriate for planting portions of bioswales, it should not be used in locations that will receive concentrated runoff. Liner, container or plug plant material is a better choice in these areas.
7) Incorporate amended soil as part of slope construction when specifying Mechanically Stabilized Embankments (MSE) for steep embankments and consult with Geotech Services. Placing amended soil at the proposed slope face can be done as part of placing each geotextile reinforced lift. An open weave erosion control blanket should be used to contain the material at the slope face by using a "wrap-back" method. The slope can be hydroseeded upon completion of the MSE.
8) Specify "stepped-slope" construction for grading cut slopes. Cut slopes are difficult to vegetate for different reasons such as rocky subsoil, compaction,

removal of topsoil and organic material, and steepness. Using a “stepped-slope” method can enhance vegetation establishment. This method involves making a series of cuts, or small benches, starting at the top of the proposed cut slope and working down. The final slope has a “stair step” appearance rather than a smooth, scraped slope. Each step should be between 2 to 6 feet wide. By allowing approximately 50 percent of the loose, excavated material to remain on each step, a planting bed is created. This planting be can be further enhanced by adding compost.

7.6 Restrictions for Plant Selection

Nearly half of the bulk solids collected in the structural treatment BMPs consists of plant litter such as leaves and twigs. To maintain the efficiency of these BMPs and especially basins and trash BMPs such as GSRDs, trees and large shrubs selected for banks of biofiltration swales should contribute minimal plant litter to the BMP. Deciduous trees and other species that contribute large amounts of bark, leaf, flower, or seed litter should be avoided.

7.7 Drainage Facilities

Accommodations for drainage facilities upstream and downstream from biofiltration BMPs should be considered as follows:

1) Provide a concrete apron large enough to prevent overgrowth and reduce clogging around drainage inlets located in bioswales.
2) Provide a concrete apron large enough to prevent overgrowth and reduce clogging at culvert inlet and outlets such as flared end sections. This enhances performance and facilitates inspection and maintenance.
3) Include armoring or other forms of scour protection such as the use of rock or turf reinforcement at the transitions from piped or other hard surface conveyance to vegetated areas.

7.8 Plant Establishment Period (PEP)

PEP ensures project success by maintaining plants during a period when mortality rates tend to be high. This is true for Highway Planting, as well as for revegetation planting that includes grasses and forbs, and especially native grasses.

The following should be considered when requiring PEP for biofiltration BMPs:

1) Biofiltration BMPs that are graded, constructed and planted as part of a roadway construction contract should have a 1-year PEP. Depending upon the type of construction and order of work, the PEP may run concurrently with other work.

2) Work to be performed during the PEP should include the following when applicable for the project:
    a) Weed control and removal of inappropriate plant species,
    b) Mowing and other vegetation management,
    c) Repair of rills, gullies, and other damage caused by erosion and scour,
    d) Reseeding of bare or repaired areas,
    e) Monitoring and repair of irrigation system (permanent or temporary),
    f) Removal of temporary irrigation system, and
    g) Removal of accumulated sediment and debris.
3) The following activities may be performed during the PEP and done as extra work:
    a) Additional planting,
    b) Additional irrigation, and
    c) Monitoring of plant growth and establishment.
4) Ideally, a 3-year contract to perform plant establishment work should follow immediately after completion of the roadway contract that installed the Biofiltration BMPs. If practical, the follow-up contract may include the Biofiltration BMPs of several construction projects in proximity of each other.

7.9 Definitions:

1) **Vegetative Cover:** *(This definition is paraphrased from the draft NPDES Construction General Permit)* Actively growing plant matter that is uniform, self-sustaining (perennial) and in contact with the soil. Live perennial vegetation may include grasses, grass like species, forbs, and some broad leaf species that are ground covers, low shrubs, or a combination. The area shall have a minimum vegetative cover of 70% within the first growing season. The remaining 30% shall be covered by fallen plant litter, standing dead plant material, or mulch. Near 100% coverage should be possible after the second growing season.*)*

2) **Temporary Cover:** Temporary cover consists of erosion control materials that provide short-term, interim protection of disturbed soil areas. Temporary cover products include erosion control blankets and other RECPs, straw, composts and mulches, and hydromulches. These products are generally composed of biodegradable and photodegradable materials with variable longevity.

7.10 Additional Resources

See locations below for additional information regarding planting methods and strategies for slope stabilization:

- The Soil Resource Evaluation (SRE) provides a stepwise process for regeneration and re-vegetation of drastically disturbed soils. Information on plant rooting depth, plant available water, soil nutrient levels, etc. can be found here. This information is linked to the HQ Landscape Architecture Program at: http://www.dot.ca.gov/hq/LandArch/research/index.htm.

- Several studies on biofiltration BMPs, erosion control, and revegetation can be found on the Caltrans Department of Environmental Analysis webpage at: http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm.
- The Caltrans Revised Universal Soil Loss Equation (RUSLE2) and the Erosion Prediction Procedure (EPP) provide a software tool and guidance for predicting surface erosion and selecting BMPs. The EPP appendixes include information on collecting and processing soil samples. (Under development)
- The Erosion Control Technology Council (ECTC) is a non-profit organization dedicated to developing performance standards, uniform testing procedures, and guidance on the application and installation of rolled erosion control products (RECPs). Information for selection and installation of RECPs based upon longevity, slope inclination, C-factor, and shear strength is given for various classes of products. Access their webpage at: http://www.ectc.org/.